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AIRCREW EMERGENCY DECISION TRAINING:
A CONFERENCE REPORT

NOVEMBER 28-30, 1978
SAN FRANCISCO, CALIFORNIA

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM																		
1. REPORT NUMBER AEOSR-TR-80-0276	2. GOVT ACCESSION NO. AD-AD83 575	3. RECIPIENT'S CATALOG NUMBER																		
4. TITLE (and Subtitle) AIRCREW EMERGENCY DECISION TRAINING: A CONFERENCE REPORT, 28-30 November 1978, San Francisco, California.		5. TYPE OF REPORT & PERIOD COVERED INTERIM																		
7. AUTHOR(s) Dr. Luigi Lucaccini		6. PERFORMING ORG. REPORT NUMBER 14 PCR-1065-79-5																		
9. PERFORMING ORGANIZATION NAME AND ADDRESS PERCEPTRONICS, INC. 6271 Variel Avenue Woodland Hills, CA 91367		8. CONTRACT OR GRANT NUMBER(s) F49620-78-C-0067																		
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research (NL) Bolling AFB DC 20332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2313A2																		
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE 1 May 1979																		
		13. NUMBER OF PAGES 90																		
		15. SECURITY CLASS. (of this report) Unclassified																		
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE																		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited																				
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)																				
18. SUPPLEMENTARY NOTES																				
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <table border="0"> <tr> <td>Aircraft accidents</td> <td>Emergency scenarios</td> <td>Procedural training</td> </tr> <tr> <td>Aircraft emergencies</td> <td>Emergency training</td> <td>Resource management</td> </tr> <tr> <td>Behavioral decision theory</td> <td>Instructional systems</td> <td>Simulators</td> </tr> <tr> <td>Decision making</td> <td>development</td> <td>Situational emergency training</td> </tr> <tr> <td>Decision training</td> <td>Pilots</td> <td>(SET)</td> </tr> <tr> <td></td> <td></td> <td>Skilled performance</td> </tr> </table>			Aircraft accidents	Emergency scenarios	Procedural training	Aircraft emergencies	Emergency training	Resource management	Behavioral decision theory	Instructional systems	Simulators	Decision making	development	Situational emergency training	Decision training	Pilots	(SET)			Skilled performance
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(3) to identify current issues and recommendations for future work. Perceptronics' own statement of the issues related to aircrew emergency decision training forms the initial paper in this report. The bulk of the report is made up of condensations of the individual papers and presentations from the conference. A section entitled "Epilogue - 30 minutes Over Florida" describes an aircraft emergency experienced by one of the participants of the conference, just ten days after the conference ended. The conference agenda and a list of participants are included as appendices. Emergency training programs were discussed from a wide variety of standpoints, including media and methods, sequencing of instruction, the role of the instructor, validation and evaluation of training programs, problems in field implementation, and the variety of audiences which emergency decision training programs are required to address. The role of emergency scenarios in training program development was reviewed and the importance of validating the procedural doctrine to be applied in response to scenarios was stressed. The need for developing scenarios which use realistic cues, information rates and time frames was pointed out. Both prospective and retrospective approaches to scenario generation are necessary to ensure that a comprehensive and relevant set of training problems are developed.

Some of the more frequent recommendations and conclusions which were brought forth at the conference include the following: (1) performance requirements in aircraft emergency situations range from rote responding to complex analysis; (2) emergency decision training should address this range of requirements; (3) training at all levels of aircrew proficiency should be considered, not just at initial levels; (4) decision theory concepts can be taught to aircrews; however, decision theory must be linked to practical applications to gain acceptance and use; (5) areas of importance include: option generation, establishing utilities, personal decision rules, and preplanning/rehearsal; (6) Instructional System Development (ISD) personnel should ensure that the systems knowledge necessary for emergency decisions is not omitted from training for specific aircraft systems; (7) training should be carried out in a manner that resembles the real life situation (e.g., via scenarios) in order to facilitate transfer; (8) ancillary cues should be defined and included in training scenarios, simulations; (9) design/development data and field performance data (incidents, accidents) should be fed to ISD personnel to update training regularly; (10) special attention should be paid to teaching difficult component skills individually and to developing strategies to deal with persistent performance problems.

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AIRCREW EMERGENCY DECISION TRAINING: A CONFERENCE REPORT

NOVEMBER 28-30, 1978
SAN FRANCISCO, CALIFORNIA

CHAIRMAN Dr. Luigi Lucaccini
CO-CHAIRMEN Major Jack A. Thorpe, USAF; Dr. Amos Freedy
SPONSORED BY Air Force Office of Scientific Research, in conjunction with the Office of Naval Research

PERCEPTRONICS

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CONTENTS

Foreword	vi
OVERVIEW	
Decision Training and the Aircraft Emergency Problem <i>Luigi Lucaccini</i>	3
INVITED ADDRESSES	
Statement of Workshop Goals <i>Major Jack A. Thorpe</i>	9
ONR Programs and Emergency Training <i>Henery Halff</i>	12
Should Pilots Need to Make Emergency Decisions? <i>Ward Edwards</i>	14
Comment <i>Paul Slovic</i>	20
Resource Management in Present and Future Aircraft Operations <i>John Lauber and Renwick Curry</i>	22
Case Study of Accident Analysis and Reporting <i>James Danaher</i>	27
Summation of Issues <i>John Lyman</i>	31

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CURRENT RESEARCH IN EMERGENCY DECISION TRAINING

Accident Analysis Methodology <i>Major Duncan Dieterly</i>	37
Requirements Analysis for Decision Training <i>Joseph Saleh</i>	40
Decision Training for ASW Helicopter Pilots <i>Antonio Leal</i>	43
Situational Emergency Training <i>Rosemarie Hopf-Weichel</i>	46
Formal Versus Situational Models of Skilled Performance <i>Hubert and Stuart Dreyfus</i>	49
Personal Factors in Emergency Decision Making <i>Carl Castore</i>	51

DECISION TRAINING NEEDS

From the Standpoint of Aircraft Accident Reporting and Research <i>Richard Davis</i>	57
From the Standpoint of Simulator Research and Training Programs <i>Elizabeth Martin</i>	59
From the Standpoint of Instructional Systems Development <i>Andy Gibbons</i>	63
From the Standpoint of Procedural Doctrine and the Precreation of Emergency Scenarios <i>Stan Roscoe</i>	67

REPORTS OF DISCUSSION GROUPS

Decision Theoretic Applications to Emergency Situation Analysis <i>Martin Tolcott</i>	71
Accident Analysis and Safety Research <i>Anchard Zeller</i>	74
Operational Training Programs <i>Gary Klein</i>	76

EPILOGUE

Thirty Minutes Over Florida <i>Rosemarie Hopf-Weichel</i>	81
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APPENDICES

Conference Agenda
List of Participants

FOREWORD

This report is the record of a two and on-half day working conference held in San Francisco, California, on November 28, 29 and 30, 1978. The conference brought together selected members of the military research support community, military contractors, instructor pilots, and other individuals concerned with aircrew training, safety research, and behavioral decision theory. Purposes of the conference were: (1) to review the state of the art of aircrew emergency decision training; (2) to review the implications of behavioral decision theory, safety research and training technology for aircrew emergency training; and (3) to identify current issues and recommendations for future work. The conference was organized by Perceptronics in connection with a sponsored research project entitled Instructional Systems Development and Situational Emergency Training, funded through contract F49620-78-C-0067 with the Air Force Office of Scientific Research.

Perceptronics' own statement of the issues related to aircrew emergency decision training forms the initial paper in this report. The bulk of the report is made up of condensations of the individual papers and presentations from the conference. The section entitled "Epilogue - 30 Minutes Over Florida" describes an aircraft emergency experienced by Lieutenant Mike Bryant, one of the participants of the conference, just ten days after the conference ended. The conference agenda and a list of participants are included as appendices to this report.

It was generally agreed that the conference was successful in reaching its goals. This was due in no small part to the speakers and other participants and their efforts must be acknowledged. The contributions of the instructor pilots and other flying personnel in attendance deserve special recognition. While it is hoped that this report captures the

essence of the technical presentations and discussions at the conference, Perceptronics remains solely responsible for the accuracy of the material contained herein.

OVERVIEW

DECISION TRAINING AND THE AIRCRAFT EMERGENCY PROBLEM

Luigi Lucaccini
Perceptronics, Inc.

An emergency is commonly defined as an unexpected occurrence of a set of circumstances which calls for immediate judgment and action to avoid undesirable consequences. The standard emergency response expected of every aircrew is three-fold: (a) to maintain aircraft control, (b) to analyze the situation and take proper action, and (c) to land as soon as practicable. In the broader context of flying safety, however, aircrews are expected to do more than skillfully resolve immediate full-blown emergencies. It is equally important that they actively avoid situations which can lead to emergencies and that they recognize the early signs of an impending emergency and take corrective action before the situation assumes crisis proportions.

Emergency preparedness, under this view, goes beyond the capability to make very rapid, accurate decisions under intense time pressure. It is a truism among experienced flying personnel that there is usually more than enough time to deal with most emergencies and, further, that it is not the first mishap, or even the second, that kills pilots, but the third. An aircraft emergency might be viewed, then, as a sequence of events (and decisions), which, if not recognized and resolved at an earlier stage, culminate in a crisis. If so, emergency preparedness training, and more specifically, emergency decision training, must accommodate the broader range of situations and skills that this conception embraces.

In the strict sense, decision making can be viewed as the efficient translation of high quality information into appropriate action by a rational decision maker using effective decision strategies. While this may be an adequate description of decision analysis, a slightly broader

view of decision making is necessary to encompass the decision activities important in the practical setting of aircrew emergency decision training. As Nickerson and Feehrer (1975) point out, decision making involves a number of overlapping aspects or phases of activity, which might best be conceived of as a series of related problem solving tasks. In our view, the following breakdown is useful in characterizing the general area of decision making:

- (1) Diagnosis.
 - (a) Problem recognition.
 - (B) Information acquisition and evaluation.
- (2) Decision-Making.
 - (a) Problem structuring and development of alternatives.
 - (b) Evaluation of alternatives and selection of a course of action.
- (3) Decision Execution.
 - (a) Implementation of action alternative.
 - (b) Monitoring of implementation and evaluation of results.

The training of emergency decision makers should accommodate the wide range of functions and underlying skills that a breakdown such as this implies. A second obvious consideration for those developing and providing emergency decision training is incorporation of the system-specific elements of knowledge appropriate to the particular aircraft system involved. A third general concern is with the economics of the training situation, namely resources, resource policies, and other factors which shape and constrain the instructional approaches that might be utilized. A fourth consideration is the degree to which training should be specific or general in nature.

The question of general versus specific approaches to decision training is not a new one and has been raised repeatedly by those who have surveyed the field (Goodman, Fischhoff, Lichtenstein and Slovic, 1976; Kanarick, 1969; Nickerson and Fehrer, 1975). All are in agreement that our understanding of this issue is hampered by a lack of theoretical guidance which is anchored to a solid body of experimental evidence. Current research in cognitive science holds some promise for those who hope to identify the common elements in decision-making strategies used in different tasks as a basis for developing general approaches to decision training.

Work at Perceptronics, Inc. (Saleh, Leal, Lucaccini, Gardiner and Hopf-Weichel, 1978) has led to the development of an approach to the systematic identification and classification of task-specific decision functions and related training objectives. This methodology has relevance to the analysis and improvement of aircrew emergency training programs, particularly for the structuring of scenarios and training exercises. It is our hope that this methodology will also facilitate the development and testing of approaches to decision training which permit some degree of generality.

The convening of a conference to review aircrew emergency decision training is an ambitious attempt to deal with a difficult and important problem. The topic itself is a complex one which represents the overlap of several disparate disciplines and interests. Moreover, the growing pressure on training systems to continue to produce highly skilled flying personnel in the face of increasingly complex aircraft systems and decreasing resources for training serves to intensify the problem. Two outcomes of this conference will be of value. The first is to call attention to this important area. The second is to provide stimulation and guidance to those wishing to advance the current state of the art. The papers summarized in this report reflect the efforts of the participants towards these goals.

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INVITED ADDRESSES

STATEMENT OF WORKSHOP GOALS

*Major Jack Thorpe
Air Force Office of Scientific Research*

One area of interest in the flight and technical training program of AFOSR is how critical decisions are made by aircrew members. This is related to an understanding of the skills which underlie successful decision making and how such skills can be developed through training programs.

Aircrew members, both pilots and others on the flying team, can be characterized in some important ways. They are highly screened, carefully selected individuals. Extensive and expensive training programs are used to bring their flying skills to a level of high quality. The responsibility they bear when carrying out missions is enormous in terms of life, equipment, and mission achievement and is rarely paralleled in other professions.

Aircrews are called on to perform in an environment for which man is imperfectly adapted. Unusual visual demands, the dynamics of flight, and an accelerated time frame for action typify flight in high performance aircraft. These are among the factors which complicate the human performance setting, and make decisions more critical and the outcome of such decisions potentially more catastrophic than in many other situations. The varied and complicated mission profiles and maneuvers of military aircrews in comparison with commercial crews require a very complex skill repertoire. The training time available to build this repertoire, on the other hand, is of necessity limited. We are faced, therefore, with a very challenging and demanding training problem.

Two approaches to aircrew emergency decision training that will be discussed at this meeting should be defined. The first, Boldface,

is a standard Air Force approach which has been in existence for many years. In Boldface, the pilot is required to memorize that part of his flight manual which describes the response procedures for various emergency conditions, those procedures being printed in Boldface type. Pilots are tested regularly on their retention of these critical actions by frequent paper and pencil tests and by less frequent simulator spot checks. The emphasis in a Boldface training approach is on memorizing these actions for broad classes of emergencies.

The second approach, Situational Emergency Training (SET), attempts to deal with the special tailoring of responses needed when the standard response under Boldface may not be sufficient. That is, a SET approach recognizes that each emergency situation has unique properties, and, while a sequence of Boldface activities might be appropriate for a high percentage of a class of situations, occasionally, the good pilot will have to modify a Boldface response.

In just about every aircrew training program, these two approaches are mixed to some extent; but with one aircraft, the operational community has made a deliberate step towards developing a situational approach. This is the F-15 air superiority fighter training program, and its use and development of SET will be described by following speakers in more detail. Other speakers will address simulator technology and innovations in ground training programs, especially ground training of emergency decision making.

This workshop will be successful in helping AFOSR set priorities for future research support if it extends our knowledge and insight regarding how critical decisions are made and how the current state-of-the-art of behavioral decision theory and training technology can be utilized to improve aircrew emergency decision skills. Another important goal for this workshop is to stimulate a more regular and comprehensive dialog among the skilled

aviators, the members of the accident investigation/safety research community, the decision theorists, and the training technologists in attendance.

ONR PROGRAMS AND EMERGENCY TRAINING

Henry Halff
Office of Naval Research

The Personnel and Training Research programs at ONR support two kinds of research which might be relevant to the concerns of this workshop. The first type of research is concerned with the psychological bases for generative, knowledge-based, computer-assisted instruction. The second area is concerned with the cognitive processes and structures underlying skilled problem solving and information processing in real world tasks. Jack Thorpe and I, in discussing this workshop, were able to think of four ways in which these research areas might apply to the problems which arise in handling emergencies.

First, Jack mentioned that one cause of accidents is pilots' failure to deal with the ongoing task of flying the airplane while he or she is dealing with the emergency itself. This phenomenon strikes me as being analogous to that found in many memory experiments involving changes in context between learning and recall. The effect of such changes is usually to make certain well-learned responses unavailable, and a similar effect might be obtained if current training practices led pilots to change psychological contexts in dealing with emergencies. Certainly situational training, to the extent that it treats emergencies in the context of normal flying operations, might be better in this regard than Boldface procedures.

A second problem mentioned by Jack was the tendency of pilots to cling to one hypothesis concerning the nature of a malfunction, long after the readily available indicators would clearly disconfirm the hypothesis. In Bayesian terms, this behavior reflects a failure to buy information in situations where such a purchase would have a very low cost-benefit ratio. But a cognitive scientist might interpret such behavior in terms of scripts, frameworks by which people comprehend particular situations, limit the range of

potential actions, and determine which features of the situation are relevant to those actions. It is not surprising, therefore, that an inappropriate script could, by idiosyncratic restriction of attention, deny the pilot access to those features of the situation which would cause him to exchange the script for one more appropriate. While such problems may not be entirely avoidable, it should be possible to discover by empirical means, and control through training, those aspects of situations which determine script selection.

A third interesting feature of emergency-handling behavior which Jack mentioned to me was the failure, particularly of novices, to consider the consequences of their actions. Horror stories of pilots ejecting in bizarre circumstances and the reported practice of pilots flying ahead of their planes indicate that mental models of the aircraft and its systems play a key role in diagnosing malfunctions and dealing with emergencies. Research on the mental modeling of real-world systems is new in cognitive psychology and not without controversy. The topic, however, is central to other important issues such as computer reasoning, mental imagery, and the relationship of procedural to declarative knowledge. It therefore provides a dramatic example of how research on a relatively narrow applied problem such as emergency training can illuminate a host of basic research issues.

A fourth, and last, issue that Jack and I discussed was the possibility of partially or fully automating situational emergency training. We have, in other fields, achieved a certain measure of success in using a computer-resident, rule-based system to represent an expert's procedural skills. Such systems could be used to evaluate a student's knowledge of the skills and to generate cases on an individual basis which are appropriate to the trainee's pattern of strengths and weaknesses. Such systems could not, I fear, represent the modeling capacity, discussed above, beyond a very superficial level, but they could serve as a useful tool to extend instructors' resources, relieve them of some of the more routine chores, and increase the pace of situational training.

SHOULD PILOTS NEED TO MAKE EMERGENCY DECISIONS?

*Ward Edwards
Social Science Research Institute,
University of Southern California*

In 1958, Alex Williams, a distinguished human factors specialist, wrote a long-forgotten technical report on tactical decision making by fighter pilots. At the time, I was relatively young, not yet a pilot, and had the familiar layman's awe-struck view of the fighter pilot as Jimmy Stewart, bashful but God-like in crisis. So Alex Williams' thesis, though completely convincing to me, was also quite startling. It has remained in my head to this day, and strongly colors all of my thinking about what one should do in preparing for potential emergencies.

That thesis was very simple, and very persuasive. It was simply that fighter pilots do not in fact make tactical decisions. If properly trained, they simply recognize pre-specified situations, whether of a routine or an emergency nature, and respond to them as they have been carefully trained to respond.

This philosophy came to its fullest fruition later, in the manned space flight program. I was a close observer of the processes by which the astronauts were trained to meet emergencies in space, and in fact I helped in the creation of some of the elaborate scenarios used in the training process. As most of you know, the entire Mission Control facility in Houston was used as a gigantic form of training device, both for ground controllers and for the astronauts themselves. A small staff under the direction of one man was responsible for inventing scenarios, keyed in detail to specific missions, in which controllers and astronauts alike had to deal with emergency situations.

In this context, I learned more about emergencies. Of course, it was one of NASA's major goals never to lose an astronaut during a mission. To

accomplish this, they not only built extraordinary layers of redundancy into their systems, but also developed extremely elaborate contingency plans for what to do in case of any reasonable set of equipment or component failures that might occur. These plans, called mission rules, did in fact provide so carefully for so many possible kinds of failures that I had an extremely hard time, working in collaboration with the simulation staff, in constructing any situation to which *anyone*, be he astronaut or controller, had to make a decision. And the head of the simulation staff, Harold Miller, commented to me late in the program that *no* emergency ever in fact arose in a real flight that had not previously been included in one of the simulation runs. (For a report of my work, see: Controller Decisions in Space Flight. In: *Applications of Research on Human Decision Making*, 1968. Washington, D.C. NASA Scientific & Technical Information Division, 1970, 93-106.)

Preplanning, then, turns the problem of decision making into the much simpler and more tractable problem of situation recognition. Once a situation has been recognized, there should be, and can be, a pre-specified and known order, to deal with it. The only "decision" a pilot, or anyone else, must then make is simply to figure out which of the numerous possible pre-specified situations he in fact is in.

How idealistic is this? Not very, I think. The basic tool, instinctively used by virtually any teacher and systematically used in NASA-like contexts, is the scenario. A scenario is simply a preplanned set of situations for the trainee to recognize, so that he can practice both the recognition and the pre-specified response to the situation. The standard engine-failure drill given to every student pilot is an example--though a crude one.

The goal, I think, should be exactly the one Harold Miller enunciated. Never let the pilot encounter a situation that he hasn't practiced before.

What can go wrong? Lots of things.

- (1) Too often, simulators are not used for this purpose. Instead of using a systematic scenario, carrying through some plausible set of malfunctions or other emergency conditions to their natural conclusion, teachers, especially when using simulators, sometimes pile problem on top of problem until all resemblance of realism is lost--along with the patience and tolerance of the trainee. I think we should spend more time than is now common in pilot training (at least as I understand it) in developing "emergency" scenarios for simulators in such a way that they make sense and are believable. The appropriate responses to those scenarios should be carefully thought through, and the trainee should clearly understand both what they are and why they are appropriate. I return to the thinking-through process below.
- (2) The set of possible emergencies cannot be exhausted in any kind of training process. Consequently, pilots will inevitably encounter situations they have not met before, have not thought about before, and must therefore respond to on the spur of the moment.

There is truth to this argument, but less of it than meets the eye. Weather is, of course, infinitely variable. Yet we find it relatively straightforward to use a quite limited number of categories to describe the aspects of it most relevant to the pilot. Ceilings, visibilities, icing, thunderstorms, rain, snow--these are rather simple ideas, yet most of what a pilot needs to know about weather emergencies can be pre-specified by use of them. And the set of inside-the-plane emergencies is far sparser--at least in general aviation.

- (3) We cannot, and should not, expect any training procedure to result in perfect safety. For one thing, selection and training-time requirements would be too high. For another, even highly trained and highly competent pilots are vulnerable to system errors. From what I have read in the newspapers, there is literally nothing that pilots of the PSA jet that went down in San Diego could have done; the fundamental problem was that light-plane touch-and-goes at Lindbergh were being controlled from Miramar. That seems to me to be a clear case of system error.
- (4) Finally, the redefinition of a pilot's role from decision maker to situation recognizer is unlikely to be popular with pilots. Even as we surrender more and more control of plane and mission to systems and procedures, and to the black boxes and remote people necessary to implement them, and notice that safety improves as a result, we resent it. I always fly IFR in VFR weather. And I always resent the delays, inconveniences of routing and the like that result.

Now I want to turn to two other questions. One is, how should preplanned responses to emergencies be chosen? Fortunately, this is relatively simple. An airplane is not a particularly complicated piece of equipment, compared, for example, to a space vehicle plus its ground control. The set of options available in a particular situation is generally sparse. Often, there is only one. If my engine quits, and I am unable to restart it, I have no option other than to look for a field. In the presence of a sparse set of options, it may not require much sophisticated analysis to pick the best one. If it does, sophisticated methods are indeed available. In fact, my own field, called decision analysis, provides them. The fundamental principle of decision analysis is that every decision should, and does, depend on the answers to two questions: what is at stake, and what

are the odds. In airplane emergencies, the stakes are often quite well-defined: people and plane. The odds are harder to get at. But a highly sophisticated technology for obtaining numerical assessments of odds exists, and is now in use for much more difficult and important decisions than the ones we are considering.

Systematic use of assessments of stakes and odds has been rare in aviation contexts. But it is perfectly feasible. In cases in which sophisticated analysis is relevant at all, which are probably rare, that, in my view, is the kind that should be used.

The other question, is in a sense, more interesting. It is this: if a pilot is, or should be, basically a situation recognizer (plus a book of preplanned responses and, in some cases, a servo-mechanism), how is he to recognize situations?

Inside the cockpit, most situation recognition is done by what might be called template matching. That is, a specific set of stimuli define a situation. Such a set of stimuli is like a template. If the situation you are in corresponds to that template, you make the response appropriate to it. Obviously, template matching can be done only if we have a complete set of templates. And equally obviously, given human fallibility, our set of templates can never be quite complete. However, if only a few low-probability templates are omitted, the situations in which the pilot must think for himself on the spur of the moment can be reduced to a minimum. And that, in my view, is a very good idea. As a pilot, I consider my own ability to think clearly on the spur of the moment to be reasonably marginal.

Outside the cockpit, the situation is different. Flying into a deteriorating weather situation in a light plane is a nice example. As turbulence increases, ice accumulates, and the weather reports from ahead of you become

increasingly ominous, when do you decide to turn and go back?

At least to some extent, this too can be a template matching situation. The concept of "personal minimums" illustrates what I mean. Though it is legal, I have never flown an approach to a 200-ft. ceiling; 400 is my personal minimum.

In some situations, template matching must be replaced or supplemented by probabilistic inference. We usually do this informally, but there are very useful, very formal ways of doing it also. Unfortunately, the formal procedures are not well-adapted to the cockpit. But they are very well adapted indeed to preplanning. In fact, they are the techniques one uses to answer the question: what are the odds?

So, let me summarize. In at least 90% of the instances that I, myself, know of, the necessity for pilot decision making in the air in an emergency situation was the result of failure of prior analysis on the ground. In my view, if the problem is created on the ground, its solution should be found there too. After it has been, what remains to be done is to teach that solution to the pilots themselves.

COMMENT

Paul Slovic

Decision Research Branch, Perceptronics

There is some interesting evidence from other fields which supports Ward Edwards' remarks about decision making in aircraft emergency situations. Studies of chess masters by DeGroot and by Chase and Simon seem to indicate that, more than anything else, chess masters are excellent situation recognizers. Similarly, studies by Elstein and Shulman of skilled medical diagnosticians show that diagnostic capability of physicians is surprisingly situation-specific. In both cases, practice that involves exposure to a wide range of specific cases or problems appears to underlie skilled performance. Extraordinary powers of reasoning and forethought do not seem to be associated with mastery level performance. Experience in a wide range of situations, preplanning of responses, and development of routinized programs for processing information seems most appropriate.

Research on judgment and decision making shows the importance of preplanning and, wherever possible, the automation of decision making. Findings from research on the diagnostic performance of physicians that support this view include the following:

- (1) Frequent failure to generate a relevant hypothesis set.
- (2) A tendency to overemphasize positive (confirming) evidence and to underemphasize disconfirming evidence.
- (3) Difficulties in integrating several pieces of information into implications about a hypothesis.
- (4) A tendency to ignore base rate considerations.
- (5) Interpretation of data to fit preconceived hypotheses only.

How does one develop adequate preplanning to avoid such problems? The process of combining information to reach a decision may be easier to model than

we think. Very specific and simple models of expert decision behavior can be developed, based on detailed observations made over a period of time. In pilot training, the behavior of experts could be captured through such modeling techniques taught to trainees.

Another important aspect of preplanning is the ability of the planner to imagine in advance how various contingencies will appear to the trainee, should they come about. Two problems emerge here. For one thing, information may be responded to differently in the real-life situation than in practice. For another, our true preferences may not surface in the practice situation. These effects are similar to the context effects mentioned earlier by Henry Halff. The analyst involved in preplanning needs to be aware of such effects and of the issues involved in determining whether preplanned preferences and responses are better than on-the-spot reactions as guides to action.

RESOURCE MANAGEMENT IN PRESENT AND FUTURE AIRCRAFT OPERATIONS

John Lauber and Renwick Curry
NASA-Ames Research Center

A human factors research group at NASA-Ames is studying commercial aircrew behavior, particularly from the standpoint of the captain of the crew. The work focusses on *resource management*, which is currently defined as: "The application of specialized interpersonal and information processing skills to achieve a crew structure and process that effectively and efficiently utilize available human and material resources in attaining system objectives." The resource management problem deals with the question of how well crew members, particularly the captain, use the resources available, namely, information, hardware, other people, and other resources (e.g., ATC).

As part of the overall research program, a study was carried out using twenty airline crews, each run on a 747 airline training simulator, to observe resource management problems during full mission simulations. Each crew flew a mission or line trip which originated at Dulles, included a 30-minute stop-over at Kennedy, and proceeded on to London. The Dulles-Kennedy leg involved a low workload scenario with routine events. The Kennedy leg involved a high workload scenario, during which significant data were collected about aircrew performance. Some of the areas in which aircrew performance problems were observed in response to the complications introduced during the high workload scenario included: (a) communications, (b) decision-making, (c) resource management, (d) crew interaction and integration, (e) manuals and charts, (f) emergency procedures, and (g) warning system design.

One important finding from the study was that the crews that managed available resources were more effective in handling the scenario. The role of the captain was particularly important in setting priorities and making use of the other crew members.

This study helped, in part, to define the resource management problem. It also helped to develop a research technique and the full mission simulation approach to training aircrews. Anecdotal data collected during the simulation runs suggested that the crews were captured by the simulation and appeared to respond to pressures and events in a natural manner. Also, the errors and problems observed corresponded nicely to those reported from studies of real flights, and to incident and accident data. The full mission simulation technique has been adopted by several airlines to meet requirements for recurrent training, and experiences at Northwest Orient in particular suggest that it is an effective training technique.

Proposed work under this general research program includes the development of a training program, as yet not fully defined, to improve aircrew resource management skills. A complementary aspect of the training program will be to measure transfer of training, using full mission scenarios as the transfer vehicle in which resource management is evaluated. The economics of aircrew training require that significant advantages be demonstrated for such experimental training approaches, both in terms of immediate transfer and long-term performance, if airlines are to modify their current training practices.

A second area of research being carried out by the NASA-Ames group deals with the level of automation in current aircraft systems. Automation is increasing in the cockpit; at the same time, human monitoring and supervising of automated systems will still be required for the foreseeable future.

Automation is a two-edged sword. It leads to increased reliability and precision, but it also introduces another level of man-machine system problems. Some of the major issues are listed below:

- (1) Erosion of competence (or skill atrophy) as a result of lack of utilization of skills.
- (2) Selection of an appropriate level of system reliability - Intermediate levels of system reliability may introduce a false sense of complacency, a problem which may not occur at high or low levels of reliability. False alarm rates and missed alarms relate to this issue.
- (3) Level of communication - How much and by what means should the automatic system tell the pilot what it is doing? Will system failures be detected more readily when the pilot is an active controller or a passive monitor? Which mode will best facilitate diagnosis of a problem and selection of a recovery response?
- (4) How can automated systems be designed so as to maintain their effectiveness in spite of individual differences in crew capabilities and operating style?
- (5) Which characteristics of automated systems should be included to make the systems sufficiently "transparent" to the pilot so that malfunctions can readily be detected?
- (6) What countermeasures can be used to alleviate the problems listed or implied above?
- (7) Development of boredom, followed by complacency, when crew functions are automated.
- (8) Impact of automation on job satisfaction.

One goal of this research program is to provide human factor guidelines for automation of cockpit functions. The *general* guidelines and working hypotheses might take the following form:

- (1) Lack of practice (six months) does not affect tracking skills unless the tracking tasks require velocity compensation (phase lead, anticipation).
- (2) Knowledge of complex procedures degrades significantly in three months.
- (3) Low levels of workload produce large variability in failure detection response (Some people do better at low levels of workload; others do worse.).
- (4) Automatic systems should perform their task "as the pilot" for more efficient monitoring and takeover.

Some hypothetical examples of guidelines specifically for *cockpit* functions might include:

- (1) Autopilots should have a capability for entering and maintaining holding patterns.
- (2) Pilots should exercise all flight control system modes at least once in three months.
- (3) Pilot flying approach should have flight director on, pilot not flying: flight director off.
- (4) Fail-passive autopilots should have easily interpretable control laws (for better failure detection) and wind shear detectors.

These issues and related guidelines indicate some of the research topics that will be pursued by the NASA-Ames group in the near future.

CASE STUDY OF ACCIDENT ANALYSIS
AND REPORTING

James Danaher
National Transportation Safety Board

About 3:00 p.m. on April 27, 1976, American Airlines Flight 625 overran the departure end of runway 9 after landing at the Harry S. Truman Airport, Charlotte Amalie, St. Thomas, Virgin Islands. The aircraft struck the instrument landing system localizer antenna, crashed through a chain link fence, and came to rest against a building located about 1,040 feet beyond the departure end of the runway. The aircraft was destroyed. Of the 88 persons aboard the aircraft, 35 passengers and 2 flight attendants were killed. Thirty-eight other persons received injuries which ranged from minor to serious. One person on the ground was injured seriously.

The National Transportation Safety Board determined that the probable cause of the accident was the captain's actions and his judgment in initiating a go-around maneuver with insufficient runway remaining after a long touchdown. The long touchdown was attributed to a deviation from prescribed landing techniques and an encounter with an adverse wind condition, common at the airport.

The non-availability of information about the aircraft's go-around performance capabilities was a factor in the captain's abortive attempt to go-around after a long landing.

Selected findings from the analysis of this accident indicate:

- (1) The captain did not follow the company procedures in landing at St. Thomas. The company's intent was to require a 40⁰ flap landing configuration for all landings at St. Thomas whenever the headwind component did not exceed 20 kn and no gusty wind conditions were present.

- (2) The use of 30⁰ flap instead of 40⁰ flap increased the landing roll, provided lower drag, lessened the decelerative capability of the aircraft, and made the aircraft more susceptible to atmospheric or aerodynamic factors which could produce a float.
- (3) The float probably resulted from either an updraft encounter, or, from an increase in lift resulting from the rotation of the aircraft, or an increase in airspeed as a result of a rapid change of headwind, or a combination of any two or all of these factors.
- (4) A successful go-around was possible immediately upon the onset of the float, after the wind dropped, and most probably after the wings were leveled. This capability became more and more marginal as the float and engine spool-down continued.
- (5) The aircraft touched down about 2,500 to 3,000 feet beyond the runway threshold. Based on these distances, it could have been stopped within the confines of the remaining runway, but a safe go-around could not be made.
- (6) Although the captain realized the remaining runway was critical with regard to stopping the aircraft, he did not know that the remaining runway was even more critical with regard to the execution of a go-around.
- (7) With adequate training as to the aircraft's performance capability and with training environment exposure to similar situations, the captain may have reacted immediately to stop the aircraft instead of attempting a go-around.

Four decisions made by the captain should be noted in the context of situational emergency training:

- (1) The choice of a 30⁰ flap setting, which was in contradiction with company policy.
- (2) The decision to land the aircraft instead of initiating a go-around prior to touchdown.
- (3) The decision to initiate a go-around after touching down.
- (4) The decision to reject the go-around maneuver and to try to stop the aircraft, but without employing maximum stopping capability.

Some factors which may have contributed to the difficulty of decision making in this case should be mentioned. First, the company directive to initiate a go-around when touchdown is appreciably beyond the aim point does not specify what "appreciably" means. Second, the turbulence, which caused a wing to dip and the aircraft to float, constituted a distraction which may be interpreted as delaying the captain's realization of the distance he had travelled down the runway. A third factor, referred to already, was the non-availability of information about the aircraft's go-around capability once the engines were spooled down. A fourth factor is that of limited prior training experience in go-arounds when available runway distance is a consideration. A fifth factor is the utility structure of the captain in relation to employing maximum stopping capability; this maneuver is both alarming and uncomfortable from the passenger standpoint and hence is not a preferred maneuver. A sixth factor is the typical pilot's unfamiliarity with employing maximum stopping capability. A seventh factor is the natural preference for choosing a go-around as the first response. This is generally the approved procedure, which pilots are rarely criticized for employing, when a landing may involve difficulties.

This particular accident is a widely remembered one. The foregoing review of the accident has some obvious implications for training, for procedures and policy revision, and for taking other precautions to avoid

a repetition of it. Since the analysis, the runway has been lengthened and obstacles at the end of it removed. American Airlines has modified its procedures and now requires that the pilot make a go-around decision no later than at the runway threshold. Although American Airlines no longer flies into St. Thomas, Eastern Airlines does, and their training department has programmed the St. Thomas approach into its simulator and requires pilots to be checked out on it and to be periodically retrained on it.

This accident is an excellent example of performance degradation, of the breakdown of otherwise well ingrained skills in an unusual context. (The article, "Managing Emergencies in Jet Transport Operations," by Gerard Bruggink, in the Summer 1978 issue of *Pilot*, presents many more related examples of emergency situations.) My hypothesis about this particular incident is that this seasoned captain experienced the unexpected, reached down then into his bag of tricks to correct the situation, and aggravated it instead of correcting it. He then realized that an overrun was inevitable and an accident was possible. This realization may have triggered the response which cancelled out the deeply ingrained, appropriate response of braking, reversing and lowering the nose.

A final point, or generalization, which can be drawn from this particular critical incident is that airline training is deficient in the area of situational emergency training. Most airline captains receive limited touch-and-go training and not under conditions which are representative of live operations with such unfavorable factors as were present in this case. The flight simulator affords an excellent and safe means of accomplishing such training and more could be done using the simulator as a situational emergency training device.

SUMMATION OF ISSUES

John Lyman
UCLA

Four general categories of issues arose during the meeting, and these included a large number of sub-issues. Each general category is discussed in turn. The first is the issue of *the degree of rote training versus the degree of abstract or decision training that is desirable*. We can't avoid dealing with rote learning of specific procedures. This is clearly important. Learning procedural rules is also important, however, for they allow more tailored responses under varying time pressures and unique situational factors. The recognition of what part of a set of procedural rules to use or not to use takes us back to the situation recognition concepts discussed by Ward Edwards and others earlier. An issue raised is the distinction between template matching and feature recognition, a fundamental difference of approach in pattern recognition theory.

Decisions require rules for operation on present data, while rote performance requires specific memory of what to do in a predetermined scenario or script. Humans are probably better oriented to the former, assembling features of a situation, then applying procedural rules. In a sense, then, the decision aspects of emergency response are continuous and need to be addressed on an integrated basis together with requirements for rote response. The training strategy implied is to facilitate learning to analyze alternatives for assembling the features of a situation into successful decision states.

The second class of issues has to do with *time management*. The time management problem in the air, in which an emergency is embedded in a set of other demands on the aircrew's time, can be a principal determiner of response capability and response adequacy. Ground training can be used to reduce reaction time, but the realism of ground training is questionable

in view of the variable and complex time management problem in the air. Simulator training crosses the bridge to some extent between the ideal and real practice of decision making, but more study is needed to better simulate airborne time management conditions as they affect decision making, as well as to improve decision making under such pressures. Time critical vs. time relaxed priorities in relation to decision process effectiveness is probably an especially important area for study.

A third general theme throughout the discussions and presentations of this meeting is the notion of *causal chains*. The problem of analyzing aircraft accidents validly in terms of contributing factors is well known. We think in terms of a sequence of incidents leading to a climactic event, and this sequence or chain is very hard to document reliably after the fact. It appears that the only "accidents" which can be adequately studied are those that occur in simulators. Generally, the reporting and coding of accident data still only tell us what happened, not how it happened. Safety research and emergency training program development are both hampered by the seeming inaccessibility of data describing these causal chains. Flight recorders have been a productive step, but clearly more is needed, perhaps including distributed sensors recording detailed data about the aircraft itself and its relation to external and internal environmental variables, including the activities of the flight crew. Video monitoring should also be considered.

The last group of issues involves *man-machine personal and technical factors*. The importance of specific technical factors of individual systems and subsystems is generally recognized in emergency situations and safety. The wide variation in individual capability is another area of importance. As John Lauber and Renwick Curry pointed out, some excellent pilots just aren't good captains. Both psychological and physiological factors could be studied to identify superior individuals in relation to their assignment.

Bio-instrumentation of astronauts is routine; perhaps more should be done along these lines with aircrews.

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CURRENT RESEARCH IN EMERGENCY
DECISION TRAINING

ACCIDENT ANALYSIS METHODOLOGY

*Major Duncan Dieterly
AFHRL Technology Office
NASA-Ames Research Center*

The work described below is part of a larger effort being carried out at NASA-Ames to study and improve resources management in a multiman aircrew operation. In this particular segment of the resources management program, the emphasis is on human error problems as opposed to equipment problems or environmental factors. The scope of interest extends beyond the immediate emergency situation and includes those performance situations in which an impending danger is not an issue though an accident can be precipitated by such a series of "harmless" errors.

The theoretical approach presented is useful for analyzing accidents but is not intended to be limited to accident analysis. It is a general theory of problem solving and decision making that fits this type of situation. Our program has three objectives, all of which are important:

- (1) To develop a technique to analyze accidents in terms of the underlying dimensions of human error.
- (2) To use the results of analyses of accidents by this technique to develop training programs aimed at reducing human errors.
- (3) To operationally reduce human errors made by aircrews and accidents.

The theoretical approach to the analysis of accidents integrates two areas of research and conceptualization, namely problem solving and decision making. These concepts are considered as functions of one process. A prescriptive *clarification process model* has, thus, been established to integrate these two conceptual areas. It consists of five phases:

- (1) Identify the situation.
- (2) Determine options.
- (3) Establish outcomes.
- (4) Evaluate/analyze.
- (5) Select option and implement.

An *information manipulation function* is a critical aspect of the clarification process model whose phases are highly dependent on information flow. The information manipulation function consists of five sub-functions:

- (1) Attaining information.
- (2) Screening information.
- (3) Standardizing information.
- (4) Classifying information.
- (5) Storing information.

A function control mechanism is postulated as governing these sub-functions in a fashion similar to the command/control mechanism in a computer. The information manipulation function is a crude model of the cognitive capability of the individual and this element of the clarification process model addresses the possible constraints of individual differences and experience in resolving particular decision/problem conditions.

Some of the ideas underlying this general approach should be described. First, accidents are the culmination of a sequence of events; if some of the events or decisions in the sequence had been handled differently, the accident would have been avoided. Second, a major decision/problem state consists of a set of related decision/problem condition sequences which are not necessarily symmetrical when compared with each other. Third, a hierarchical model, which is a modification of the classical decision

tree, serves to incorporate many aspects of reality that the decision tree does not and, as a result, depicts the decision/problem state in a more useful fashion. The hierarchical model permits display of these features of decision/problem states:

- (1) Differences in importance or criticality of the various individual decisions.
- (2) Differences in the timing of events in each decision/problem condition sequence and among sequences.
- (3) Differences among sequences in the number of decisions.
- (4) Association together of all sequences whose outcome is successful decision/problem resolution and similar separate association of those sequences which result in failure.

The clarification process model affords a means to look at the process followed by individuals and aircrews when faced with various situations and to identify process errors and information problems. With such knowledge, strategies can be developed and taught for resolving specific decision/problem conditions and states successfully. From a research standpoint, the approach outlined here has clear value for the development of a taxonomy of decision/problem conditions in relation to which generalized, rather than situation specific, decision/problem resolution skills might be taught.

REQUIREMENTS ANALYSIS FOR DECISION TRAINING

*Joseph Saleh
Perceptronics, Inc.*

The work I am going to briefly describe was carried out as part of an effort sponsored by the Naval Training Equipment Center in Orlando, Florida and is reported more fully in a February 1978 technical report ("Analysis of Requirements and Methodology for Decision Training in Operational Systems," NAVTRAEQUIPCEN 77-C-0005-1). In this presentation, I will present an overview of our basic methodology for deriving training requirements, and Tony Leal will provide an example of our application of it for ASW helicopter pilot training.

There are three steps essential to the derivation of requirements for a decision training program. They are: (1) identification of decision tasks, (2) classification of the identified tasks, and (3) association of instructional methods, media and content with particular tasks.

The *identification* of decision tasks comes from an analysis of training materials, procedural doctrine, and interviews with experts. We generally find that decision tasks are hidden or embedded within more straightforward, larger procedures. For instance, part of a task might be stated as: "Identify the contact as a natural object, friendly ship, or enemy ship." The operator is told what should be accomplished, but not *how* to do it. He is left to make the decision on his own. One approach that has served us well in initially screening such tasks is the use of keyword analysis. There is enough consistency in military publications and informal doctrine that certain words such as "analyze" and "determine" frequently flag tasks which have decision components.

Classification of identified decision tasks represents the second major phase of activity. We employ a number of dimensions for classification. Primary among them is a determination of which major components of decision making are involved in the task. The following schema represents our breakdown:

- (1) Problem structuring.
 - a. Formulation of alternatives.
 - b. Establishment of outcomes.
- (2) Alternative selection.
 - a. Assessment of utilities.
 - b. Assessment of probabilities.
 - c. Application of decision rule.
 - d. Selection of best alternative.

Decision tasks can involve just problem structuring which we term a Type 1 decision problem. Once the problem is well structured, the choice of alternative is given or is straightforward. Other decision tasks may involve alternative selection only; that is, the identification of alternatives and their outcomes is obvious. These are referred to as Type 2 decisions. Those decision problems which involve both problem structuring and alternative selection are referred to as Type 3.

We also classify decision tasks according to several other attributes, as exemplified by the following questions:

- (1) Are the alternative outcomes single attribute or multi-attribute?

- (2) Is the task performed by an individual or by a group?
- (3) Is the task static over time or dynamic with respect to the timing of actions and results?
- (4) Is the task a one-shot activity or is it repetitive?
- (5) Is the task performed under certainty or risk?
- (6) Is the task concretely defined or ambiguous?
- (7) Does the task involve decision making or just decision execution?
- (8) Is the task performed under time stress or not?
- (9) What is the distribution of task outcomes with respect to negative results?
- (10) What is the appropriate decision rule?

The last major phase is *generation of instruction guidelines*. Instructional content, as it relates to the various aspects of decision making listed above, is selected for the instructional designer in the form of a content overview with examples. This is integrated in training development with the specific aspects of the real world decision task which underlie the problem. Instructional media and methodology are also recommended to the developer based on an analysis of the cognitive requirements for the particular decision task.

The instructional guideline generation system was realized in computerized form as a small program that interrogates a training specialist and then produces a set of design guidelines. This experimental demonstration not only rapidly produces a printed prescriptive guide, but also unburdens the designer of the need to perform the calculations that support the generation process. A more complete description of the methodology and of the supporting work is contained in the technical report, and I refer you to it for further details.

DECISION TRAINING FOR ASW HELICOPTER PILOTS

*Antonio Leal
Perceptronics, Inc.*

Perceptronics recently concluded a one-year research and development program in the decision training area which had the following specific objectives:

- (1) To review, from a decision analysis standpoint, the tasks which constitute the Navy SH-2F (LAMPS) ASW Pilot/ATO and Sensor Operator job functions and identify those which were decision tasks.
- (2) To select a small set of decision tasks from the larger set of decision tasks identified.
- (3) To describe in detail one specific decision task.
- (4) To develop a method for classifying decision tasks and establishing training techniques for such tasks.

This work was sponsored by the Naval Training Equipment Center at Orlando, Florida. The study was carried out at the Naval Air Station, North Island, which has an excellent helicopter pilot training program. We drew on a variety of data sources in carrying out our analyses. Courseware, Inc. has produced an excellent training syllabus and about 80 slide-tape presentations all of which were reviewed. In addition, Courseware made available instructional objective hierarchies which summarize the pilot's functions and serve as the background for detailed training. We also interviewed instructors and student pilots, all of whom were extremely cooperative.

Our analysis revealed that within this very comprehensive course there was a large number of decision tasks which were not proceduralized. In essence, at certain points in the training the student was required to realize that a judgement was called for when executing a procedure.

Development of the capability for such judgements was not addressed in the didactic instruction; rather, it is anticipated that students will develop the capability to make these decisions through experience on training flights and through conversations with instructors and fellow pilots.

We settled on one particular situation, failure of the engine, and carried out a detailed decision analysis of the alternative actions and their outcomes. A very extensive decision tree was prepared with the aid of LAMPS pilots which showed the probabilities of events and the utilities for the various outcomes. From this particular analysis, we branched out to identify some ways to describe the various characteristics of emergency and routine decisions. Four dimensions emerged which seemed important in classifying decisions which are taught to LAMPS pilots:

- (1) Well defined vs. ambiguous.
- (2) Single attribute vs. multi-attribute.
- (3) Time pressured vs. time-relaxed.
- (4) Static vs. dynamic.

The single attribute/multi-attribute dimension refers to whether the decision outcome has one or more value dimensions which need to be considered when determining payoff. Static/dynamic refers to whether the consequences of the decision are constant over time or not. The other two dimensions are straightforward.

We looked also at the various decision rules that pilots might employ in making various types of decisions. These included among others, maximizing subjective expected utility, lexicography, and satisficing. Pilot interviews revealed that their decisions generally followed one of these well-known decision rules, and the one used depended on the situation, but they were not aware of the formal rules nor were they consciously trying to follow a particular rule.

The remainder of our work involved two efforts. First, we matched each of the classes of decisions, categorized along the dimensions described, with the appropriate decision rule. Next, we looked at instructional methods and media to match these to particular classes of decision tasks. The result was an instructional guidelines generation system which is a procedure to take a specific decision task and provide guidelines for the instructional developer which specify: (1) instructional contents, (2) instructional method, and (3) instructional media.

Our general conclusions were that the types of decision tasks that we encounter could be effectively analyzed by decision analysis techniques and that formal decision rules were compatible with existing procedures. Also, a formalized instructional guideline generation system was realized which we feel has applicability to other areas in addition to LAMPS operations.

SITUATIONAL EMERGENCY TRAINING

*Rosemarie Hopf-Weichel
Perceptronics, Inc.*

Our overall program objective is to establish a theoretical basis for a systematic approach to decision training, specifically for aircraft emergency situations. The work in progress is sponsored by the Air Force Office of Scientific Research and relates to earlier work on situational emergency training done at Williams AFB. There are some parallels of this project in the work described by Antonio Leal with LAMPS helicopter pilots, namely identifying decision training requirements within the context of certain aircraft emergencies, analyzing the instructional requirements, and generating the basis for more effective training. A particularly important output of our current effort will be the development of guidelines for generating scenarios for emergency training. Another important aspect of this work will be to develop means to monitor the effectiveness of training to improve it and to establish its validity.

The basic responsibility of a pilot in an emergency is to analyze the situation and take proper action. In relation to this, we are hoping to apply decision making principles both for problem structuring and alternative selection. Our methodology follows generally that which was outlined by Joseph Saleh. We expect to rely on principles from decision theory and decision training in order to analyze emergency decision tasks and to develop a set of requirements for training. We will focus on development of personal decision rules, on training to utilize relevant information, and on development of scenarios that are systematic and comprehensive in terms of training requirements.

Our methodology involves developing a taxonomy of emergency situations, analyzing certain situations in terms of decision making requirements,

and designing guidelines for scenario generation which match emergency situations to decision making principles and paradigms. The information sources we have used include the literature on decision theory and decision training, accident reports, pilot and expert interviews, flight and training manuals, and site visits to a number of bases.

One useful exercise we carried out, based mainly on accident reports, was to establish a skeleton decision structure for a classic emergency situation, namely fire and explosion in the air. A skeleton emergency situation was developed from review of reports of a number of related accidents and used to structure interviews with several pilots in order to correct it and validate it for accuracy and completeness.

We also developed a matrix of emergencies by flight phase with the help of subject matter experts, particularly the staff at ONR in Pasadena. The matrix helped us identify particular situations for more detailed study as prototypes of critical decision training problems. It helped us identify those attributes of particular situations which we might be interested in, such as: safety criticality, time criticality, and current decision-making effectiveness.

One goal we have is to develop some general principles for generation of emergency situation scenarios that incorporate both the complexity of the emergency itself, and the decision-making aspects of the situation. In part, this could involve the identification of relevant situational factors, by flight phase, for various emergencies and the specification of variations in these factors which impact on complexity as discussed above.

In conclusion, the approach to scenario generation we are taking is systematic with respect to malfunctions as well as decision training; it allows for graduated difficulty of training problems, identifies items to be

included in future decision aids, should facilitate evaluation of decision making skills, and will involve the user in an ongoing dynamic process in the development of guidelines and scenarios.

FORMAL VERSUS SITUATIONAL MODELS OF SKILLED PERFORMANCE

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University of California, Berkeley*

Our goal is to understand how one can achieve highly skilled performance both in coping with a wide variety of routine situations and with the abnormal situations known as emergencies. Levels of skill can be roughly classified into three categories: novice, proficient and master. Simply stated, our question is whether skilled performance at any of these three levels can be made explicit and formalized.

The most naive approach to this problem is to suppose that skilled performance can be captured or described in the form of a list of specific procedures applied to explicit context-free features. A simple example of this approach could come from chess playing where a beginner learns to trade pieces so as to maximize material balance in terms of the point values traditionally assigned to the various pieces. This approach is obviously too simple. No one would seriously maintain that more than novice performance could result from following rules which operate on features that even a beginner can recognize.

A more sophisticated approach would involve the use of maxims. Maxims are procedures whose use requires a thorough familiarity with the domain to which they apply. For example, a chess maxim is: avoid an unbalanced pawn structure. There are, of course, no rules by which a novice could determine whether a pawn structure was unbalanced. Our contention is that while proficient performance can be attained in this way, mastery cannot be reached.

Evidence suggests that the analytic, information processing approach to skill development actually works against development of mastery level

skill. Study of top level performance shows that given natural talent and a great deal of experience and practice, a fundamental change takes place in the performer. This change might be described as entering the world of the activity. For example, expert pilots no longer feel that they are flying the plane, but rather that they are flying. Flying has become like walking, something one does without detaching oneself from it. The chess player becomes absorbed in the world of the game. The tennis player no longer has to strain to keep his eye on the ball, but becomes fascinated by what the ball is doing. One might argue that the master has unconsciously developed and is using better maxims, but the adaptability of expert performance suggests that no such rigid rules are being employed.

There is evidence from studies on non-analytic concept formation that giving people maxims and trying to sharpen their analytic mind actually inhibits the transition from proficiency to mastery. From our perspective, nothing but talent, considerable experience and a long learning curve plateau can lead to mastery. If one wants to manage training programs so that master performance results, we strongly advise trainers and training designers to avoid maxims, which engage the analytical mind, and suggest they speak to trainees directly from within their own world of expertise.

PERSONAL FACTORS IN EMERGENCY
DECISION MAKING

Carl Castore
Purdue University and AFHRL/FT, Williams AFB

In recent years, I carried out a series of studies together with Dr. Siegfried Streufert on various aspects of the decision making/decision implementation process. Although the studies were not done in the context of flying, the results may have some implications for aircrew emergency procedures. Briefly, our studies looked at the effects of several variables, including information load and the relevance of information. The study setting was the Tactical and Negotiations Game, an experimental simulation described in the literature. Some of the aspects of decision making studied included information search activities, respondent decision making, and integrated decision making.

Of particular interest to the aircraft emergency situation is the case in which objective external criteria are not readily available to the decision maker in the form of feedback to evaluate the decision and take corrective actions. The basic results of these laboratory studies for that case show that the ability of individuals to take individual bits of information and coordinate them into integrated decisions is best at moderate levels of information. When the decision maker's responses must be written out, seven to ten pieces of information can be handled well in a twenty to thirty minute period. If the requirement to record actions is removed, the time period may shrink by about one half. In any case, our results show that it is difficult for individuals to process very much new information effectively in a relatively short time period, one which is much longer than that found in many aircraft emergencies. At high levels of information load, integrated decision making is replaced by respondent decision making, a situation in which individuals simply respond to each issue as it arises without coordinating information or coordinating decisions.

The effects of irrelevant information are particularly illuminating. At low levels, irrelevant information was mostly ignored, assuming moderate-high levels of relevant information; however, if overall information was low, irrelevant information was integrated with available relevant information. Moderate levels of irrelevant information triggered a great deal of information search activity, as well as attempts at integrating irrelevant information with task requirements. High levels of irrelevant information produced high levels of information search, coupled with high levels of respondent decision making. It seems that at high levels of information load, individuals have difficulty sorting out relevant and irrelevant information, but continue to seek out information without being able to integrate it effectively.

How does this all relate to the aircraft emergency? In my work at Williams, I am exploring possible relationships, relying in part on pilot interviews for interpretive data. One finding is that pilots engage in a great deal of preplanning. They anticipate problems and rehearse responses both on the ground and in flight when the situation permits. This allows the pilot to stay ahead of the aircraft, to avoid the situation in which he must simply react without time to integrate new information. In this context, Boldface represents a way to aid the less experienced pilot when he is in a situation whose information processing demands exceed his capability. Boldface gives that pilot something to do right away. With a more experienced pilot, one who is able to handle the cognitive preprocessing or analysis of what can go wrong based on his detection of some early, subtle cues and in light of his knowledge of the aircraft's systems, a more sophisticated approach to emergency training seems indicated.

Another of our laboratory findings that seems to apply to the emergency setting is that people delay in making decisions when there is no clear-cut, objective criterion or feedback. They may engage in far more information search than is actually needed. In the multi-person crew, this could lead

to coordination problems among individuals who disagree about what the actual situation is. The impact may be to hamper decision implementation, that is to hinder the coordination of the steps necessary to resolve the problem.

A problem that is most intriguing from a research standpoint is that of avoiding the integration of irrelevant information into a decision. Individuals are more likely to integrate irrelevant information into a decision process when there are low levels of information involved than otherwise. The resultant decision may be technically correct, given the information used, but can lead to an undesired outcome. Similarly, the cases in which aircrews seem to focus on one particular piece of information, such as the fixation on the landing gear light that occurred in the Eastern Airlines accident in the Everglades, demonstrate the effects of failure to coordinate information and decision making. Although I don't have any ready answers to improve aircraft emergency procedures, I feel that a better understanding of the problems of aircraft emergencies from the standpoint of the aircrews themselves will increase the applicability of the research I have briefly described to this area.

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DECISION TRAINING NEEDS

DECISION TRAINING NEEDS FROM THE
STANDPOINT OF AIRCRAFT ACCIDENT
REPORTING AND RESEARCH*Richard Davis*
USC Safety Center

Accident investigation reports in the Air Force are the result of a detailed, exhaustive process carried out by a board of officers who are supported in their investigation by a variety of technical experts. While the job these boards do is a very commendable one, training research and development personnel should understand the limitations on these reports and also on the data which is eventually stored.

One limitation is in the area of identification of accident causes. The current data bank of abstracted Air Force reports includes only what might be described as primary causes. Second level, or root, causes are normally not included. At best, root causes are available only as the result of tedious analysis of the full reports themselves. It is very difficult, therefore, to develop an in-depth definition of training requirements from a study of computerized accident report summaries. A second limitation has to do with the encoding process. Reports are summarized for entry into the computer by encoders who are not experienced aircrew members. The potential loss in translation is great. A third factor which limits the usefulness of accident reports is the tremendous amount of scrutiny that reports receive up through the chain of command before they are released. Knowing that this critical analysis will take place, accident boards are somewhat reluctant to include information which is not the equivalent of possessing legal sufficiency. These are some of the facts of life which research and ISD personnel should be aware of when relying on current accident reports and data banks.

We should not overlook the fact that in the past twenty-five years we have made great strides in preventing aircraft mishaps. In the Air Force,

the accident rate has dropped from about 60 major accidents per 100,000 flying hours to about 3. The major improvement has been in the hardware area. The next challenge is to deal with the human factors contribution to accidents. Although some feel that the human factors problem cannot be dealt with any more effectively than at present, unless we face this challenge we'll never know if progress in this area is possible or not.

DECISION TRAINING NEEDS FROM THE
STANDPOINT OF SIMULATOR RESEARCH
AND TRAINING PROGRAMS

Elizabeth Martin
AFHRL/FT, Williams AFB

The role of the aviator as an active information processor, systems manager, and decision maker is being addressed in several research programs at the Flying Training Division. Although none of these efforts deals directly with emergency training research, there are several ongoing programs investigating various facets of cognitive processes under differing task loading and stress situations. The findings of these research programs should be directly applicable to decision training needs across a variety of piloting tasks, including emergency situations. A brief description of these programs is included below, along with a point of contact for each effort.

Within the basic research program, two efforts deal with the relationship between behavioral and physiological indices of pilot functioning. One effort deals with establishing relationships between a set of physiological indices of attention and task load with various behavioral measures known to be sensitive to task difficulty. The objective is to define a set of measures which is most consistently related to behavioral responses on information processing tasks which represent a realistic approximation to actual flight. (Point of Contact: Capt. George Buckland.)

Another related effort is investigating the relationship between stress in the aircraft and stress in the simulator and how simulator training may be used to alleviate some of the negative stress related performance effects observed during flight. (Point of Contact: Gary Reid.)

In the exploratory development research program, two efforts are ongoing which relate to the pilot's ability to deal with problems encountered in

flight. One effort, entitled Dynamic Problem Solving, attempts to define and teach to the student pilot those processes characteristic of an experienced pilot that enable him to make rapid and accurate decisions relevant to changing flight requirements. Initial research concentrates on navigational problems in terminal area orientation. Application to (simulated) emergency situations is one of the test conditions which will be used to evaluate the instructional procedure. (Point of Contact: Capt. David Pohlman.)

Another line of research deals with performance measurement of higher-order aviating skills (e.g., situation awareness, judgement, aircrew coordination), which are not typically addressed by conventional stick-and-rudder measurement sets. The research approach relies on the ability to create situations in a simulator which have been shown to require the relevant skill. Through repeated exposures to these situations, pilots could be ranked on a continuum of that skill. The validity of the approach would be determined by correlation with flight evaluations. (Point of Contact: Elizabeth Martin.)

In almost any discussion with pilots regarding emergency procedures training or performance measurement, the concepts of judgement, position awareness, and cockpit discipline arise. The commonly held tenet is that these processes cannot be taught or measured directly, and that they develop almost exclusively as a function of flight experience. Indeed, it seems to be the case that the lack of these processes is far easier to measure than their presence. All too many hazardous and accident-producing situations have been ascribed to lack of judgement. In addition to reported cases, informal inquiry suggests that most pilots have such experiences. (Fortunately, the most frequent results are acute stress, lingering embarrassment, and lessons learned.) It seems apparent that flying training programs require increased emphasis on the development of judgement. This presentation addresses the potential of simulation to train judgement.

The distress of many pilots and policy makers over the increasing pressure to replace aircraft flight time with simulator training is due, in part, to the fear that simulator experience cannot produce equivalent growth in airmanship skills.

The primary research problem seems to be the validity of simulation for training and assessing the airmanship skills of a pilot. The standard research technique of transfer of training experiments is, for the most part, infeasible. Establishing a correlational relationship between simulator behaviors and checkride evaluations is possible, but unlikely to be a sufficiently sensitive technique.

A thorough analysis of the factors contributing to the lack of judgement (position awareness, aircrew coordination, and the like) is a necessary first step. For example, an informal preliminary analysis suggests that many situations are not the result of faulty training or lack of awareness, but rather of a deliberate decision derived from subjective assessment of alternative contingencies.

A preliminary determination of which factors can be adequately simulated and trained via a simulated approach would be the next step. The range of simulation concepts need not be restricted to the full mission simulator but should include such techniques as mental rehearsal and observational learning.

Development and evaluation of experimental training packages would serve as a trial evaluation. Transfer of training of rule governed behavior to novel situations would constitute the test environment. Selection of the most appropriate problems for inclusion in operational programs would follow from the previous step.

My opinion is that such a research program will demonstrate that simulation can play a positive role in both the training and assessment of airmanship

components, but that some operational contingencies will need to be modified in order to make a successful transition to effective training.

DECISION TRAINING NEEDS FROM THE STANDPOINT OF INSTRUCTIONAL SYSTEMS DEVELOPMENT

*Andy Gibbons
Courseware, Inc.*

Developers can profit from an awareness of decision training needs both during training and during training development.

During Training Development: There is a growing recognition that instructional systems development (ISD) includes more than producing audio-visual materials. Such concepts as job task analysis, instructional sequencing, system and strategy design, and formative evaluation are now widely accepted as important and valuable elements of the development process. Proper employment of development techniques can produce training systems which are both efficient and effective. To enhance the effectiveness of emergency training, the developer can pay attention to the following issues during development:

- (1) The sequence of instruction should be emphasized--the series of experiences encountered by the student progressing toward mastery. Situational Emergency Training (SET) can be an effective training procedure when used properly, but it is only one step of several the student passes through in becoming proficient in emergency management. Developers should pay careful attention to the student's experiences before and after SET to insure that all integrate into a steady building progression of knowledge and motor skills. In doing this, the developer should insure: (1) that all prerequisite items of knowledge have been identified and instructed prior to SET, (2) that especially critical or difficult component behaviors are trained in isolation prior to training in context with other behaviors so that learning

of the component does not interfere with integration of the larger behavior, (3) that an appropriate family of training devices is provided through systematic device design procedures, particularly, adequate low-cost intermediate level devices which can relieve scheduling pressures on more expensive, more heavily-used devices.

- (2) Developers should insure that a continually-functioning pipeline has been set up to supply updated information on malfunction identification and emergency procedures which can be incorporated in revised versions of the instruction. It is an all-too-common experience that the training system is the last to know this information which could prevent much wasted instructor effort, much confusion, and some safety hazards.
- (3) Developers should devise instructional systems which maintain themselves in such a way that the decision-making they do is not lost in the future. To do this, an audit trail of decisions made must be created, and guidelines for making future decisions made must be created, and guidelines for making future decisions must be set up, if possible through proceduralization of the decision process. Too often, a well-running instructional system is rendered inoperative or obsolete by decisions made which invalidate the planning and decision-making of the developer.

During Training: Careful management of training system operation can also increase the effectiveness of emergency management training. The higher the level of proficiency expected of course graduates, the more careful the management of the training must be. Some suggested areas of improvement might be the following:

- (1) Instructor training should emphasize techniques which have a demonstrated effectiveness and emphasize the importance of following those instructional procedures whenever possible. Instructors should be discouraged from making arbitrary or idiosyncratic changes to the training program. Instead, they should be given a well-defined set of techniques (SET is one example) that will supply the student with appropriate levels of coaching, feedback, and demonstration. The instructor need not be taught to be a servant to the technique, but adequate training should be given to the instructor to demonstrate the benefits of using it.
- (2) Sufficient resources must be devoted to training, and cuts in the resources must be weighed in terms of potentially reduced student capabilities. Cuts to training system resources can come in different forms: (1) reduction of total equipment and personnel resources, (2) expansion of the student group, forcing allocation of fewer resource hours to individual students, (3) requirement for higher graduate performance levels with no increase in resources. All of these have the effect of moving the student more rapidly through training, forcing the student to take larger and larger steps, cutting review and refresher practice, allowing less time for the consolidation of newly-learned information. When training resources are reduced, an expected reduction in graduate capabilities should also be expected unless demonstrably more efficient techniques of instruction are employed to make up for the loss.
- (3) The training system must be insulated from external pressures to change the sequence or amount of training without full consideration of the consequences. Too often, changes to the training are mandated without careful identification

of need, and without determination of the implications for graduate capability. The changes may be absolute necessities, but they should be accompanied by an adjustment in expectations of course graduates.

DECISION TRAINING NEEDS FROM THE STANDPOINT OF
PROCEDURAL DOCTRINE AND THE PRECREATION OF
EMERGENCY SCENARIOS

Stan Roscoe
University of Illinois

There are three platitudes relevant to this topic:

- (1) To train pilots to make good emergency decisions, we must first know how systems actually work and fail. This includes knowing how pilots fail in emergencies.
- (2) We must learn all we can from the relatively few accidents that do occur, not only what happened, but *why* it happened.
- (3) We must avoid the natural tendency to narrow the blame for accidents, to minimize the appearance of widespread negligence.

Corresponding to these three platitudes are three needs:

- (1) We must establish the optimum procedural doctrine to cope with both equipment and human defections.
- (2) We must establish mission training scenarios that are pregnant with opportunities for bad decisions to occur and for breakdowns in the trained procedures that we've learned.
- (3) We need to extend training to situation recognition that includes recognition of your own temporary impairment.

In the St. Thomas incident, the procedural doctrine was at fault. The directive to go-around if touchdown were to be beyond 1,000 feet from threshold could not be carried out if the engines were spooled down. Procedural doctrine should be tested by the airlines and/or the FAA to determine its validity before it is issued.

The interaction between crew members and the rapid pressurization of the cabin prior to touchdown in the St. Thomas incident represent factors that may have contributed directly to the incident. These were not fully investigated by the NTSB, and the crew members themselves did not recall them as significant. Nevertheless, we must create an investigative atmosphere in which surviving crews are encouraged to remember everything that they can. Perhaps some sort of protection against jeopardy is needed for testimony of crew members. Some form of encouragement for complete disclosure is needed if we are to learn all we can through accident analysis.

This incident is a reminder that there are many marginal flying situations around the world. Those situations need specific situational training scenarios that pre-create emergency conditions as widely as we can predict their possible occurrence. At the same time procedural doctrines, such as those concerning flap settings for approach and go-around at St Thomas, should be tested for such marginal situations to ensure that the doctrine is appropriate to specific operational situations.

REPORTS OF DISCUSSION GROUPS

DECISION THEORETIC APPLICATIONS TO EMERGENCY SITUATION ANALYSIS:
REPORT OF DISCUSSION GROUP A

Martin Tolcott
Office of Naval Research

This workshop group focused on the potential that decision theory holds for the training of aircrews. Operational training personnel in this group characterized current training systems as follows:

- (1) Current training now results in adequate levels of emergency decision performance. (Proposed modifications to current practices must be justified as improvements with measurable benefits if they are to be adopted.)
- (2) Aircrew emergency functions cover the continuum from routine responding to complex decision making.
- (3) Training techniques must be diverse to allow for the wide range of functions required of aircrews in emergencies (as noted above).
- (4) Theoretical decision concepts must be linked to practical applications in order to gain acceptance and use.
- (5) Training at all levels of proficiency--novice, journeyman, and expert--is important.

Several proposals were put forth by the workshop group. Those achieving some degree of consensus are listed below:

- (1) Pilots must make inferences, but responses should be as preplanned as possible to permit rapid (post-inferential) responses. Training in making inferences could usefully include learning to make probability estimates, provided that this is done for specific situations (e.g., estimation of likelihood of various equipment malfunctions). Another

area of training in making inferences is learning to update probabilities as new data becomes available, especially the significance of data dependencies and independencies for situation diagnosis. Training should include the learning of system models and malfunctions at the level of detail needed for malfunction diagnosis, and not at a more detailed level. The statistical processes underlying inference should be taught; there is evidence that when physicians are trained in concepts of probability and utility their diagnostic capability is improved.

- (2) Training in option generation should be considered as one way to avoid the natural tendency to adhere to the first option that comes to mind, and to help counteract the common finding that as an emergency situation proceeds, the option list held in mind tends to get narrower and narrower.
- (3) Analyses of operational emergency procedures (e.g., Boldface) show that such procedures *do* include decision points, even though they are not identified as such. Decision points should be clearly identified in training; also two types of decisions should be added to traditional training: (a) the decision that an emergency does exist and (b) the decision about how much time exists to resolve the emergency.
- (4) Utilities need to be considered somehow in emergency training, although utilities are hard to teach and not very useful when an immediate response is required. The concepts of priorities for action and trade-offs are considered now in operational training. An extension of these training concepts to include utilities and risk-taking might be helpful, particularly in responding to particular scenarios and in the post-performance review by instructor and student.

- (5) Decision aiding should be further examined for its relevance both to training and to regular mission support. Aiding can take a number of forms, including display of symptoms, recognition of symptom patterns, and display of appropriate response sequences.

A few issues were briefly mentioned that deserve further research attention:

- (1) Determination of the most difficult tasks or decisions to teach, analysis of the learning problems underlying their difficulty, and development of instructional strategies for teaching these difficult-to-learn tasks.
- (2) Training to avoid emergencies, that is, training to recognize when the limits of the aircraft performance envelope are being approached.
- (3) Use of decision theory models and decision trees as means of communicating decision concepts during training of operational personnel.

ACCIDENT ANALYSIS AND SAFETY RESEARCH:
REPORT OF DISCUSSION GROUP B

Anchard Zeller
Hq AF Inspection and Safety Center/SEL, Norton AFB

An old saying in aviation is that "Pilots love to fly, but pilots hate to die." This saying underscores the need for academicians and members of the commercial research community to ensure that their efforts are *seen* as relevant to operational problems. Many of the aviation research studies done each year fail to have an impact on operational problems because the developers and researchers do not come up with products that convince operational personnel that safety is enhanced. A closer dialog is needed between the research and the operational communities to bridge this gap and ensure that useful products result, which operational personnel will adopt.

Accidents need to be considered in a systems context. The machine, the man, and the interface of these two system components must all be addressed. The most obvious way to reduce aircraft emergency decisions is to improve the reliability of the aircraft. A second approach to improve safety is to improve the interface of man and aircraft by providing good, easy-to-interpret information and responsive controls.

At the human component level of the man-machine system, three elements should be noted: perception, decision, and response. Some individuals seem to be naturally better decision makers; others have biologically superior perceptual mechanisms. The implications for selection are clear. Those individuals who are better able to concentrate on the critical aspects of decision making should be sought out in selection processes.

Two other related factors briefly touched on in this group were emotions and motivation. The first is particularly important and deserves further research. Aircraft emergencies all involve some level of stress; the correspondence between training decision making in the more relaxed (simulated) situation and performing in the real emergency situation needs to be studied further to enhance transfer of training.

OPERATIONAL TRAINING PROGRAMS: REPORT OF
DISCUSSION GROUP C

*Gary Klein
Klein Associates*

This workshop group covered six main areas. The first was whether formal decision analysis procedures apply to aircraft emergency decision training or not. The consensus was that no matter what labels were chosen (decision making, problem solving, and the like), they did not.

A second topic was how to set up an operational emergency decision training program. A basic starting point was identified as establishing the program's desired outcomes, then working backwards to develop the training regimen. Evaluations of such programs should be of the control group vs. experimental group type, rather than using the transfer of training approach.

Performance in training should be measured in terms of reactions to scenarios. This raises the question of scenario selection; operational training personnel felt it would not be difficult to select appropriate scenarios, while others recommended the selection be based on analysis of accident data to identify the important training areas.

A fourth area of discussion was the problem of defining an emergency. It was suggested that anything which had potential for an emergency be included in a broad classification, but there are practical problems with this idea. Little consensus emerged with respect to a satisfactory definition. All agreed that we lack a generally acceptable definition. The concept of emergency interacts with many conceptual variables such as pilot skill, preceding and concurrent events, and the like.

The fifth area of discussion covered what the ideal emergency decision training program content might include. Abstract training on decision

analysis was ruled out, as noted earlier. A straightforward approach was recommended in which trainees would be trained on the same specific emergency situations that they were to be evaluated on. Thus, the standard approach to skill development used in any other training program is recommended.

A final area dealt with by the group was training considerations specific to aircraft emergencies. They are listed below:

- (1) While it may be possible to develop psychological stress in simulators, it currently isn't possible to introduce physiological stress (e.g., high G forces, nystagmus) in simulators. Perhaps one way to prepare aircrews for physiological stresses during aircraft emergencies would be to study their effects on decision processes and at least acquaint crew members with the possible interactions that may occur.
- (2) Task analyses of emergencies should include identification of the special cues (sound, motion) that need to be included in training programs. Such cues are typically not available in manufacturers' information or elsewhere.
- (3) Collection of aircraft performance data early in the manufacturing process would facilitate the training development process. Such information should include assessment of interactions between components made by different subcontractors.
- (4) A question yet to be answered in training development is: "What specific knowledge does a pilot need to analyze complex situations and predict the outcomes of different reactions?" A related question is: "How do ISD assumptions affect this knowledge base?" The typical ISD decision to eliminate all academic ("nice to know") information may undermine the development of the pilot's basis for complex analysis.

- (5) In the context of time management and prioritization, the group discussed the need to blend two tasks: (a) flying the plane and (b) responding to the emergency. Training emergency procedures out of context, such as in the CPT, seems to ensure that pilots will respond to emergencies in a focused way and forget the larger picture.
- (6) The question of looking at other devices besides simulators for emergency decision training was raised, but no specific alternatives were identified.
- (7) A final conclusion was that management decisions should be scrutinized to find ways:
 - (a) To make instructor pilots available for training rather than for other activities.
 - (b) To make training more efficient.
 - (c) To interface emergency training with overall mission training.

EPILOGUE

THIRTY MINUTES OVER FLORIDA

*Rosemarie Hopf-Weichel
Perceptronics, Inc.*

INTRODUCTION

The following incident was reported by Lieutenant Mike Bryant, USN, one of the attendees at the Aircrew Emergency Decision Training Conference. The events reported occurred on a routine S-3 training flight that was conducted just ten days after the conference. The incident not only may hold some human interest value for those who heard Lieutenant Bryant describe his views on emergency training at the conference, but may serve to illustrate the type of situations and related decisions which emergency decision training programs can address.

INCIDENT

On December 9, 1978, Lieutenant Bryant was conducting a routine training flight in an S-3 over Florida. He is an experienced S-3 pilot, having logged some 2,000 flying hours in S-3s and having experienced eleven engine shutdowns while in flight. He had a student as a co-pilot, was 45 minutes into the flight, had leveled off at 28,000 feet, and was at normal cruise speed (about 0.65 Mach) when he experienced a pending dual engine failure.

Lieutenant Bryant and his co-pilot were preparing to put on their oxygen masks, a precautionary procedure required above 27,000 feet, when they began to smell smoke similar to exhaust gas in the aircraft. The smell of smoke continued for a few minutes, then the number two engine gauges started to fluctuate a bit. The probability of getting a whiff of Environmental Control System (ECS) exhaust in the cockpit is quite high;

it happens frequently in the S-3, but usually at lower altitudes. It is also common for a gauge to fluctuate a little, as the result of a loose wire, for example; but it is not common for all or most of the gauges to fluctuate at the same time.

Although Lieutenant Bryant was not alarmed, he was aware that something was probably amiss. There was a little more smoke and fluctuation of the gauges, and suddenly the smoke increased greatly and all the gauges, except the oil pressure gauge, were fluctuating wildly. These events strongly suggested that engine number two was coming apart. Lieutenant Bryant had at this point two options -- to shut down engine number two or to continue to operate with both engines. The first course would reduce the development of further damage or problems with engine number two and involved little risk since the S-3 flies well with only one engine, assuming there are no other serious malfunctions. The latter option runs the risk of fire, explosion, or flame-out. Lieutenant Bryant quickly chose the first option. He shut down engine number two and started his descent to avoid pressurization problems.

After shutting down an engine, standard (Boldface) procedure requires the pilot to land as soon as possible, unless there are extenuating circumstances. In this case, there were no contraindications to landing and his next decision was to evaluate the various landing possibilities and select one. There are several factors to consider in choosing an emergency landing site. The most important of these is distance, in compliance with the requirement to land as soon as possible, although distance must be weighted against weather conditions, availability of arresting gear and crash crews, the type of emergency, and similar considerations.

For Lieutenant Bryant, the choice was fairly simple. There were two Navy bases and two Air Force bases in his general vicinity. All things being equal, he would have selected a Navy base since it would have appropriate maintenance facilities. Lieutenant Bryant's maintenance crew was at Cecil, 150 miles away, and was his preferred choice with respect to available facilities. There was, however, a cold front between his position and Cecil, and it was raining at Cecil. The other Navy base, Pensacola, was 100 miles away. Both of these fields were further from him than the two Air Force bases: Eglin, about 80 miles away, and Tyndall, about 50 miles away. In this case Tyndall was the best option with respect to all remaining factors. If Tyndall had been closed because of weather, the second choice would have been Pensacola. Eglin is undesirable for an emergency landing because it has several landing areas and a pilot cannot know ahead of time where he will be directed to land. "They can vector you to maybe 90 miles away," according to Lieutenant Bryant.

Arresting gear was available at all four airfields. For this case, it represented an extra safeguard. If engine number one had failed instead of engine number two, arresting gear would have been mandatory. The functioning of the utility hydraulics, which include the main brake system, nosewheel steering, and landing gear extension, depends on engine number one.

Following shut-down of engine number two, Lieutenant Bryant had declared an emergency with Jacksonville Center, the controlling agency that provided him with distances to the nearby airfields. After considering the factors described above, he decided to land at Tyndall and remained in radio contact with the center as he proceeded toward it. At about 9,000 feet and some 20 miles from Tyndall, the situation worsened. The entire plane started to vibrate. There was a great deal of noise, and engine number one

appeared to be failing. These cues were much more striking than the cues preceding shut-down of engine number two and are typical of an impending catastrophic engine failure. The best course of action appeared to be to restart engine number two if possible and then shut down engine number one. Three attempts at restart of engine number two were made, but without success.

Since engine number two could not be restarted, Lieutenant Bryant considered three options: attempting to land immediately on the nearest highway, ejecting, or continuing to fly towards Tyndall. He decided against attempting to land immediately or ejecting. His strategy was to continue flying as long as things "got no worse" and to eject if they did. His criteria for ejection were subjective in that they depended on the perception of a "significant" change in noise, vibration or gauge readings for engine number one.

Lieutenant Bryant continued toward Tyndall without further deteriorations of the situation. As he neared the field it was necessary to select an approach for landing. The normal procedure would be a 10-mile, straight-in, radar-controlled approach. Conditions permitted a visual, 3-mile, straight-in approach which he selected to expedite landing.

During the hectic conditions of the last 20 miles, Lieutenant Bryant and his co-pilot managed to follow all the checklist procedures for a precautionary landing except for dropping gas. They did so on final approach and landed without problems. Immediately after landing, the cockpit filled with smoke. Lieutenant Bryant shut down engine number one and the auxiliary power unit, and he and his co-pilot left the cockpit head first, fearing fire. After verifying that the engine was not on fire, Lieutenant Bryant returned to the cockpit and the airplane was towed to a hangar.

Lieutenant Bryant is qualified as a maintenance check pilot. He contacted his maintenance crew at Cecil by telephone and with their assistance discovered that a failure had occurred in the Environmental Control System turbine. The failure had caused a backup in the bleed air system, producing smoke in the cockpit. This is not a classic turbine failure; in fact, the ECS turbine had never failed in this particular way before. After Lieutenant Bryant discovered the true nature of the malfunction, he determined that the aircraft could be safely flown to Cecil as long as the ECS was not in use, and returned to base without further problems.

COMMENT

The entire incident lasted about thirty minutes. The failure of the ECS turbine produced symptoms characteristic of a dual engine failure. Although the true nature of the S-3 malfunction was not determined until the emergency had passed, the pilot was still able to deal effectively with an evolving series of decisions and managed the overall situation so that risks to life and aircraft were minimized.

It is interesting to note that the emergency that Lieutenant Bryant faced was not a unitary decision problem which could be easily solved by application of a single, standard response procedure. Boldface procedures were important in the management of the emergency, but in themselves were not sufficient for resolution of the situation. There were, in fact, a series of decisions made by Lieutenant Bryant, some of which primarily involved diagnosis and others which mainly involved structuring action alternatives and choosing among them. In addition to decision making, the pilot was required to execute the results of his decision making. All of these phases of activity (situation diagnosis/problem structuring, alternative generation/selection, and decision execution) should be addressed in emergency decision training programs, both as

separate functions and as part of an integrated approach to the management of an emergency.

The role of experience in this particular emergency should not be overlooked. The pilot's experience led him to the reasonable assumption that engine number two was failing and the decision to shut it down was then rapidly made. However, his experience did not include exposure to the rare event of an ECS turbine malfunctioning in this particular way. As a result, he did not entertain other hypotheses besides engine failure or feel that it was worth the risk to continue operating engine number two long enough to obtain disconfirming evidence (e.g., to confirm the normal reading of the oil pressure gauge over a longer period of observation). He chose to minimize maximum loss by shutting down engine number two. Experience was also a factor in the rapid evaluation of landing alternatives and selection of the best site. Finally, experience was a factor in establishment of the personal decision rule to consider ejection only if the cues from engine number one got "significantly" worse.

Emergency decision training programs can address the experience factor in various ways. One is to adjust the complexity of training problems to match the sophistication of the trainee so that learning is optimal. Another is to ensure that trainees are exposed to realistic base rates of malfunctions and other emergencies and to various combinations of situational factors. In this way, acquisition of skills in comprehensive decision making and decision execution will be facilitated. The importance of designing training scenarios in light of such principles is obvious.

A final point to be made is that incidents such as this one represent a valuable source of information both for revising emergency procedures and for generating training problems and scenarios. Following his experience,

Lieutenant Bryant gave a seminar to other S-3 pilots and wrote up the incident for the Navy Unsatisfactory Material Reporting System to ensure dissemination of the experience. He also revised his personal decision rules, given a recurrence of these same symptoms, namely to include turning off the ECS in order to eliminate ECS malfunction as one competing hypothesis to engine failure.

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APPENDICES

CONFERENCE AGENDA

AIRCREW EMERGENCY DECISION TRAINING

San Francisco, California

TUESDAY, NOVEMBER 28, 1978

- 0845 Welcome
 Luigi Lucaccini, Perceptronics
- 0855 Introduction and Overview of Conference
 Jack Thorpe, AFOSR
 Henry Halff, ONR
- 0915 A Decision Theoretic Context for Emergency Situations
 Ward Edwards, USC
 Discussant: Paul Slovic, Perceptronics Decision Research
- 1035 Operational Aircrew Emergency Programs
 Moderators: Robert Lawson and Jack Battenburg, ONR
 Panelists: Current and Former Pilots, Instructor Pilots and
 ISD Personnel
- 1330 Current Research on Emergency Decision Training and Performance
 Moderator: Amos Freedy, Perceptronics
 A. *Accident Analysis Methodology - Duncan Dieterly, AFHRL,*
 NASA-Ames Research Center
 B. *Requirements Analysis for Decision Training - Joseph Saleh,*
 Perceptronics
 C. *Pilot Decision Training - Antonio Leal, Perceptronics*
 D. *Situational Emergency Training - Rosemarie Hopf-Weichel,*
 Perceptronics
 E. *Explicit Models by Rules vs. Situations - Hubert and Stuart*
 Dreyfus, University of California, Berkeley
 F. *Personal Factors in Emergency Decision Making - Carl Castore,*
 AFHRL, Williams AFB
 Discussant: John Modrick, Honeywell
- 1700 Social Hour
- 1800 Group Dinner

WEDNESDAY, NOVEMBER 29, 1978

- 0900 **Decision Training Needs**
Moderator: Robert Jacobs, Hughes Aircraft Company
A. *From the Standpoint of Aircraft Accident Reporting and Research - Richard Davis, USC Safety Center*
B. *From the Standpoint of Simulator Research and Training Programs - Elizabeth Martin, AFHRL, Williams AFB*
C. *From the Standpoint of Instructional Systems Development - Andy Gibbons, Courseware*
D. *From the Standpoint of Procedural Doctrine and the Precreation of Emergency Scenarios - Stan Roscoe, University of Illinois*
- 1050 **Case Study of Accident Analysis and Reporting**
James Danaher, National Transportation Safety Board
- 1400 **Small Group Meetings**
A. *Decision Theoretic Applications to Emergency Situation Analysis - Leader: Martin Tolcott, ONR*
B. *Accident Analysis and Safety Research - Leader: Anchard Zeller, Office of the Inspector General, Norton AFB*
C. *Operational Training Programs - Leader: Gary Klein, Klein Associates*
- 2000 **Training Technology Demonstration**

THURSDAY, NOVEMBER 30, 1978

- 0900 **Resource Management in Present and Future Aircraft Operations**
John Lauber and Renwick Curry, NASA-Ames Research Center
- 1020 **Reports of Discussion Groups**
Moderator: Gershon Weltman, Perceptronics
Panelists: Discussion Group Leaders
- 1120 **Summation of Issues**
John Lyman, UCLA
- 1150 **Concluding Remarks**
Jack Thorpe, AFOSR
- 1200 **Adjourn**

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